487

DISTRIBUTION AND SEASONAL OCCURRENCE OF *Gymnodinium breve* ON THE WEST COAST OF FLORIDA, 1954-57

by John H. Finucane

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CONTENTS

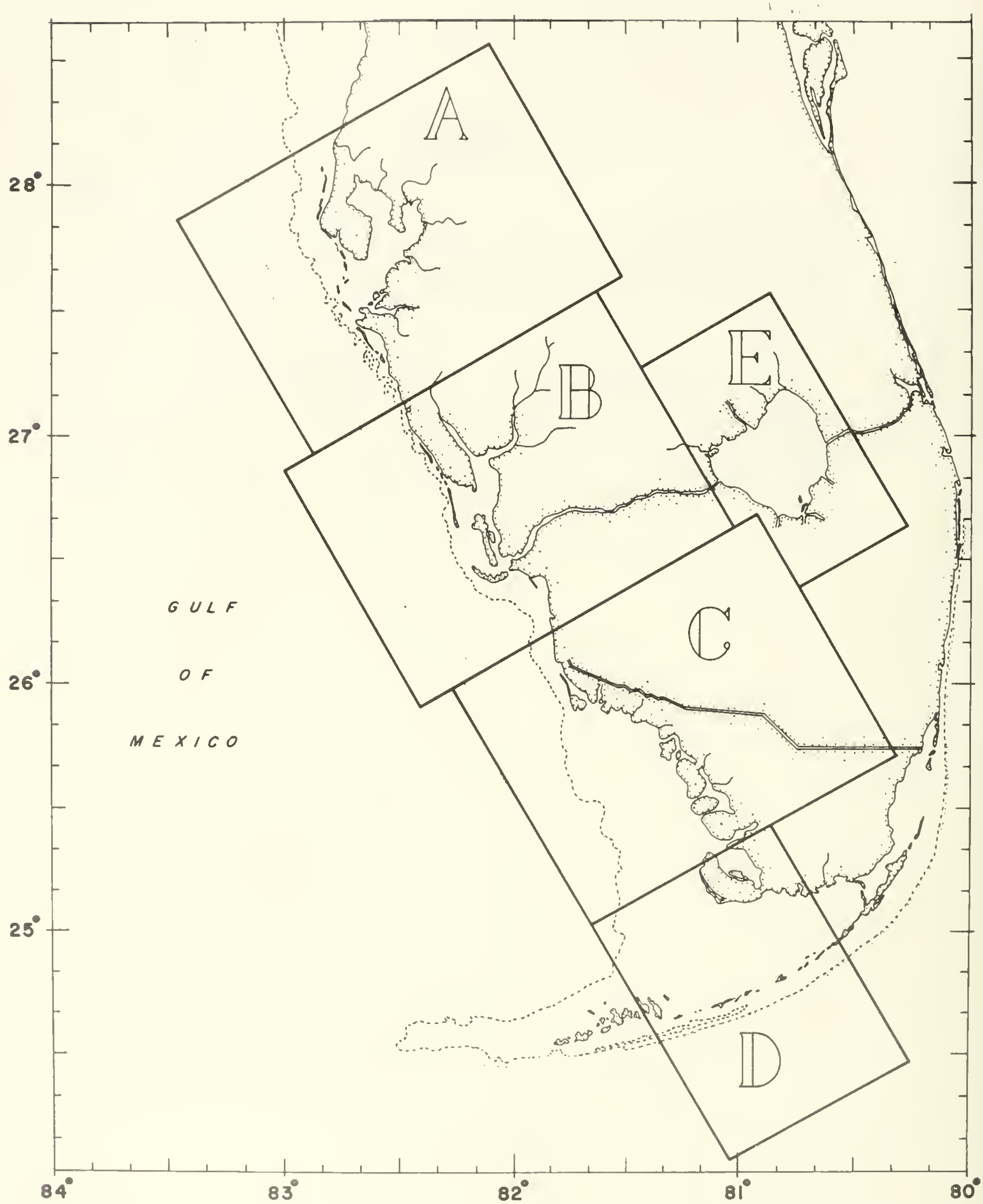

Figure 1.--Index map of southern Florida.

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by

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ABSTRACT

The distribution and seasonal occurrence of Gymnodinium breve, the Florida red-tide organism, was recorded for a 4-year period in estuarine and and neritic waters along the Florida west coast. G. breve was found throughout the year in the area from Tarpon Springs south to the Florida Everglades. Blooms of this dinoflagellate occurred mainly from September through December in 1954 and 1957. Essentially, both 1955 and 1956 were not red-tide years. The observed salinities, temperatures, and distribution of G. breve are presented during both bloom and nonbloom periods.

INTRODUCTION

This is the seventh report on field studies of the red tide in Florida's coastal waters by the Bureau of Commercial Fisheries. The red-tide organism associated with mass mortalities of marine animals and discoloration of water off the west coast of Florida was first described by Davis (1948) as a new dinoflagellate species, Gymnodinium brevis. Ray and Wilson (1957) and Starr (1958) showed that this organism produced a toxic substance(s) lethal to fish. Hutton (1956) reviewed the earlier red-tide literature covering the outbreaks of 1946-47 and 1953-54. More recent observations on the importance of dissolved nutrients, salinity, and meteorological conditions were reported by Collier (1958), Aldrich and Wilson (1960), and Hutton (1960) respectively. Chew (1961) noted the association of red tides with hydrographic conditions off the southwest Florida coast. Dragovich (1963) reported on G. breve, other plankton, and hydrology off Naples, Fla.

Prior to our investigation of this red-tide organism, little was known of its distribution. Our objective was to determine its distribution and seasonal occurrence during bloom and nonbloom years in an area extending from Tarpon Springs to the Florida Keys. The effects of salinity and temperature on distribution of this organism were also studied.

MATERIALS AND METHODS

The sampling areas and station locations are shown in figures 1-5. At the beginning of the red-tide research program in February 1954, sampling was confined mainly to areas of fish kills, and no stations were occupied south of Cape Romano. Systematic biweekly or monthly sampling of the entire area of investigation was begun in 1955 and continued through 1957. Most sampling was confined to bay and offshore waters. Fresh-water canals, Lake Okeechobee, and the upper reaches of the Caloosahatchee and Peace Rivers also were sampled (figs. 2-5). In this report, all passes, bays, sounds, and river mouths were termed estuarine waters. Neritic waters included all adjacent coastal areas in the open Gulf. All offshore sampling stations were in the latter category, and the majority of them were located within the 10-fathom (fm.) contour (figs. 2-5). Half of the stations were between sea surface and 2 fm. in areas A through D. Numbers of G. breve, enumeration techniques, sampling methods, and associated oceanographic data were previously reported by Finucane and Dragovich (1959) and Dragovich, Finucane, and May (1961).

The term "bloom" represents any concentration of G. breve exceeding the normal population level of approximately 1,000/l. G. breve counts of more than 250,000/l. were considered lethal during red-tide fish kills.

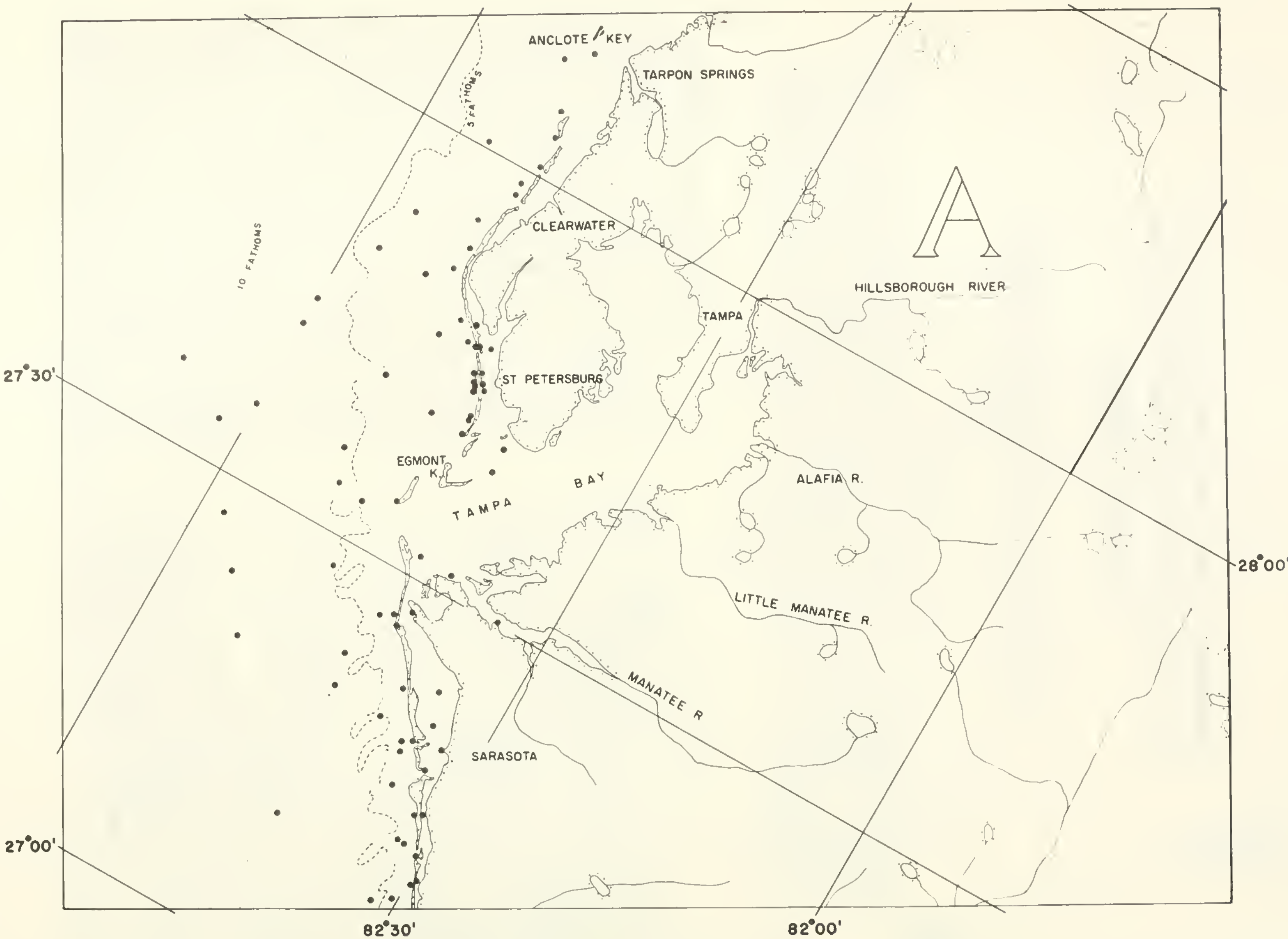

Figure 2.--Station locations in Tampa Bay area.

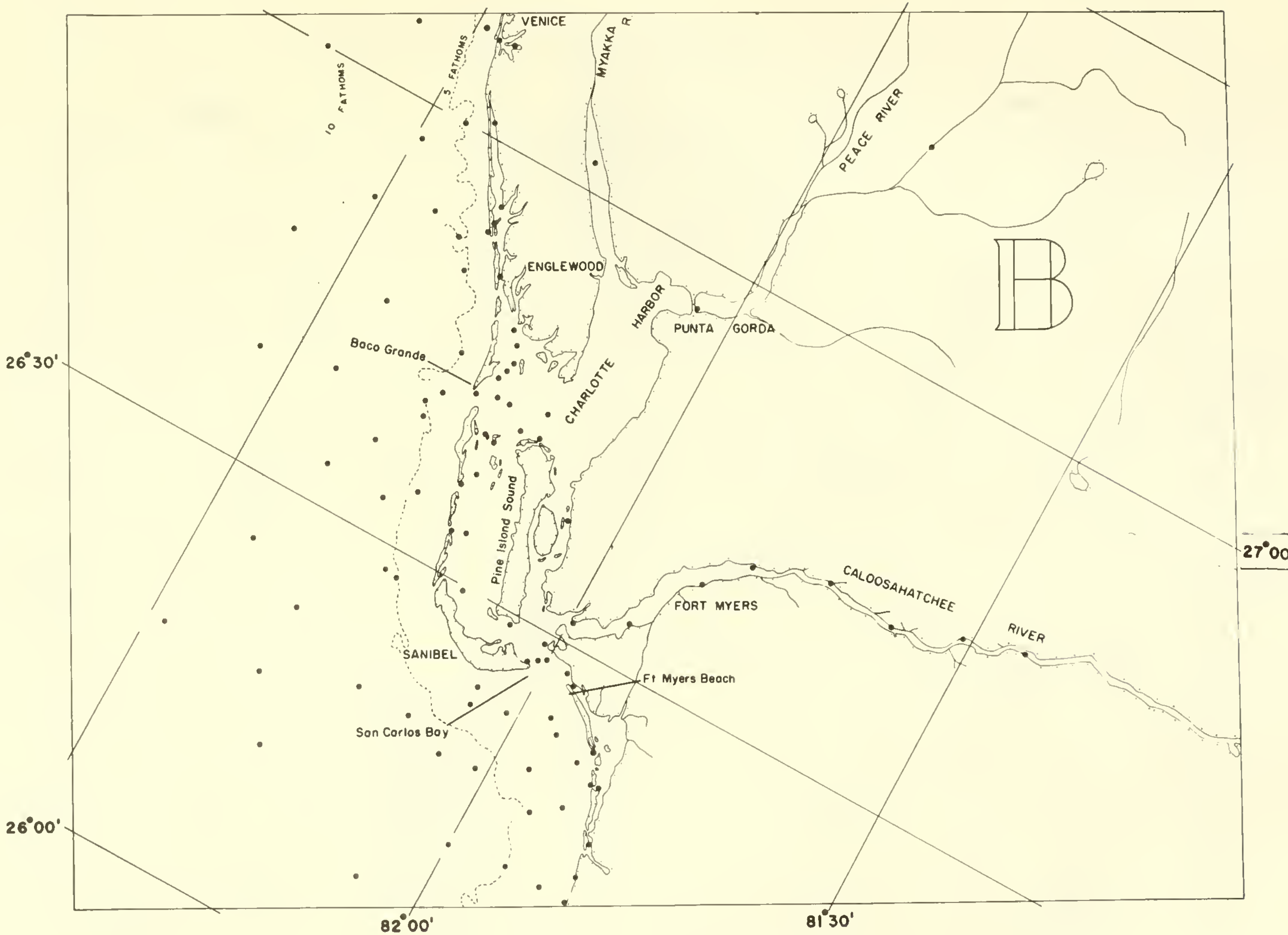

Figure 3.--Station locations in Charlotte Harbor area.

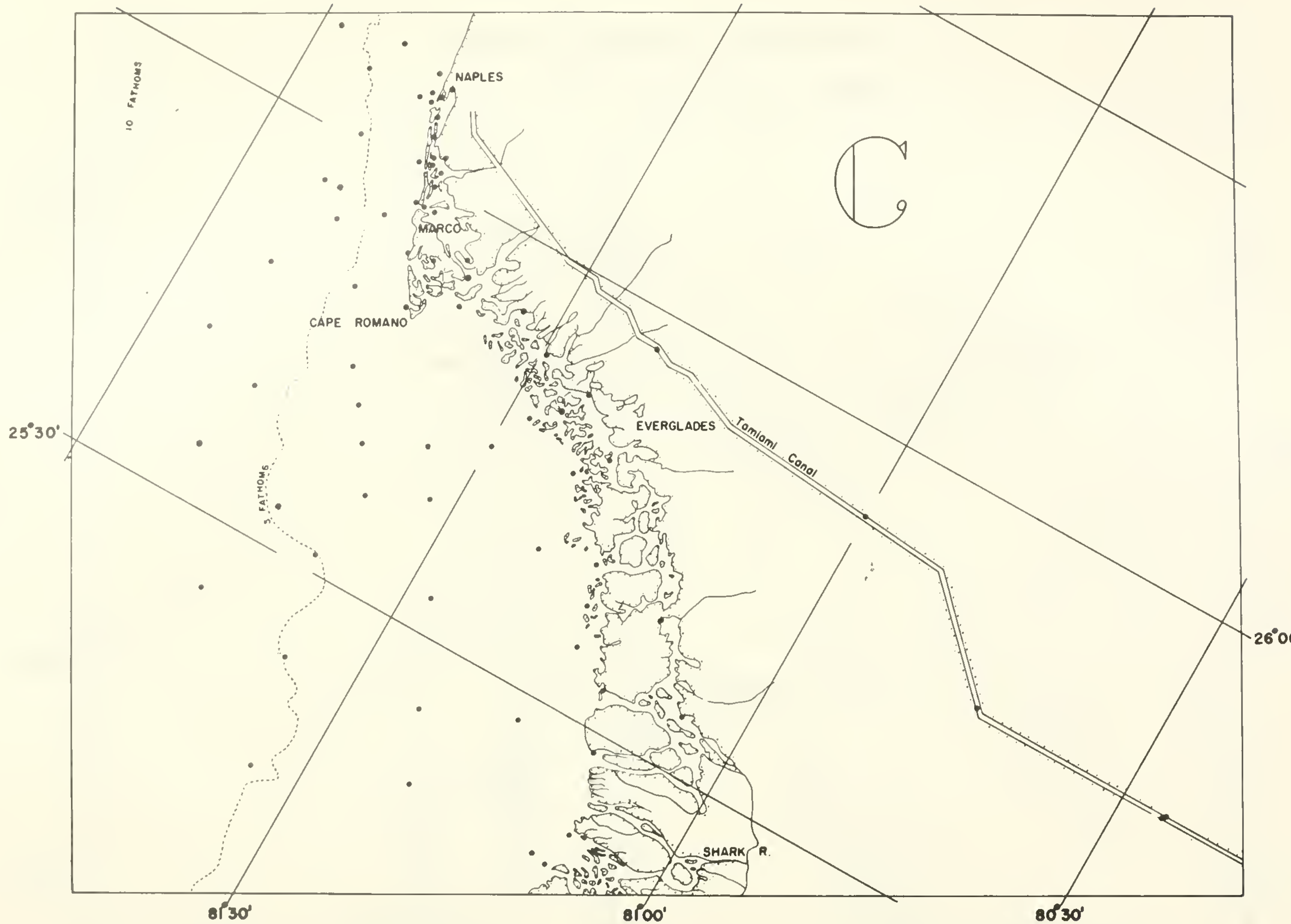

Figure 4.--Station locations in Florida Everglades area.

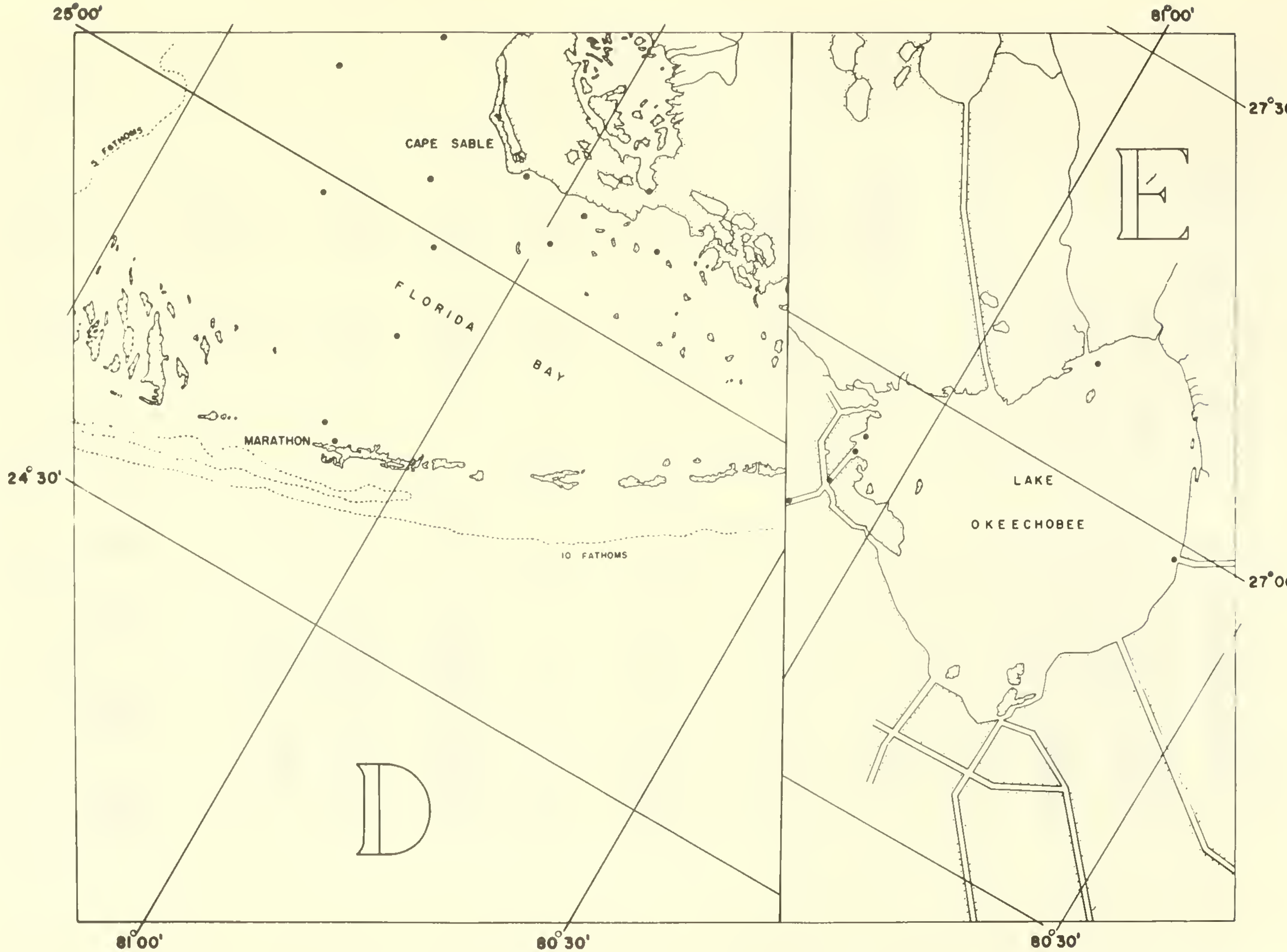

Figure 5.--Station locations in Florida Bay and Lake Okeechobee.

RESULTS

Distribution of G. breve by Area and Time

1954.--G. breve occurred in areas A, B, and C throughout most of the year in both estuarine and neritic waters (fig. 6). Most G. breve were found in areas B and C, from Venice south to the Florida Everglades. There was no sampling in area D. From January-February, G. breve occurred only in areas A and B (table 1). During March-June, the organism was found widely distributed in both estuarine and neritic waters of areas A through C. Numbers of G. breve at this time remained less than 1,000/l. (fig. 6). Although G. breve incidence decreased during July and August (table 1), isolated G. breve concentrations as high as 10,000/l. were noted in areas B and C (fig. 6). From September-December, G. breve was densest in areas B and C, mainly from Boca Grande south to Cape Romano. At that time, G. breve concentrations increased to over 500,000/l., and fish kills occurred off Wiggins and Gordon Passes near Naples.

1955.--Essentially, 1955 is not considered a red-tide year. The incidence of G. breve in all areas during 1955 was less than in 1954 (table 1). The highest incidence and numbers of G. breve were noted during January-February in areas B and C, from Sanibel Island to Cape Sable. The January maximum (1,250,000/l.) appeared to be a carryover from the previous calendar year and was noted 7 miles south of Sanibel Island. During the rest of the year, widespread low concentrations of G. breve were observed in all areas (fig. 6). In contrast to 1954, G. breve occurred infrequently throughout the summer and fall of 1955. G. breve was absent in the relatively few samples taken in area D south of Cape Sable to the Florida Keys.

1956.--No fish kills occurred, and G. breve remained below 1,000/l. in all areas. The yearly incidence of G. breve increased in area A, remained essentially the same in area B, and decreased in area C as compared to 1955 (table 1). In area C, G. breve was noted only in the neritic waters (fig. 6). No G. breve was found in area D.

Table 1.--Bimonthly and yearly incidence of G. breve given in percentage for all samples in areas A to C (1954-57)

Area	Jan.-Feb.	Mar.-April	May-June	July-Aug.	Sept.-Oct.	Nov.-Dec.	Yearly Total
(1954)							
A	53.3	33.3	57.6	16.1	40.0	11.1	40.3
B	88.2	73.8	44.8	41.2	46.3	79.0	57.5
C	0	35.5	50.0	33.3	64.9	78.3	51.7
Total	63.9	55.8	49.1	33.3	48.6	75.9	
(1955)							
A	0	0	0.9	1.5	0	2.2	1.0
B	82.7	0	2.3	3.4	0.5	10.2	7.2
C	60.2	9.4	0	1.0	0.8	5.8	9.2
Total	37.2	5.3	1.4	2.3	0.4	6.5	
(1956)							
A	0	0.9	0	0	13.4	15.4	6.4
B	1.4	1.7	0.4	3.4	4.8	23.7	7.7
C	0.7	2.2	2.4	3.0	0.8	6.8	2.8
Total	0.7	1.7	1.1	2.6	6.4	15.6	
(1957)							
A	9.2	30.3	7.4	13.9	71.2	82.5	49.7
B	15.9	17.0	13.1	10.5	38.3	85.4	28.4
C	8.0	7.6	4.5	10.6	20.0	62.0	16.3
Total	11.4	14.8	10.3	11.8	60.8	78.8	

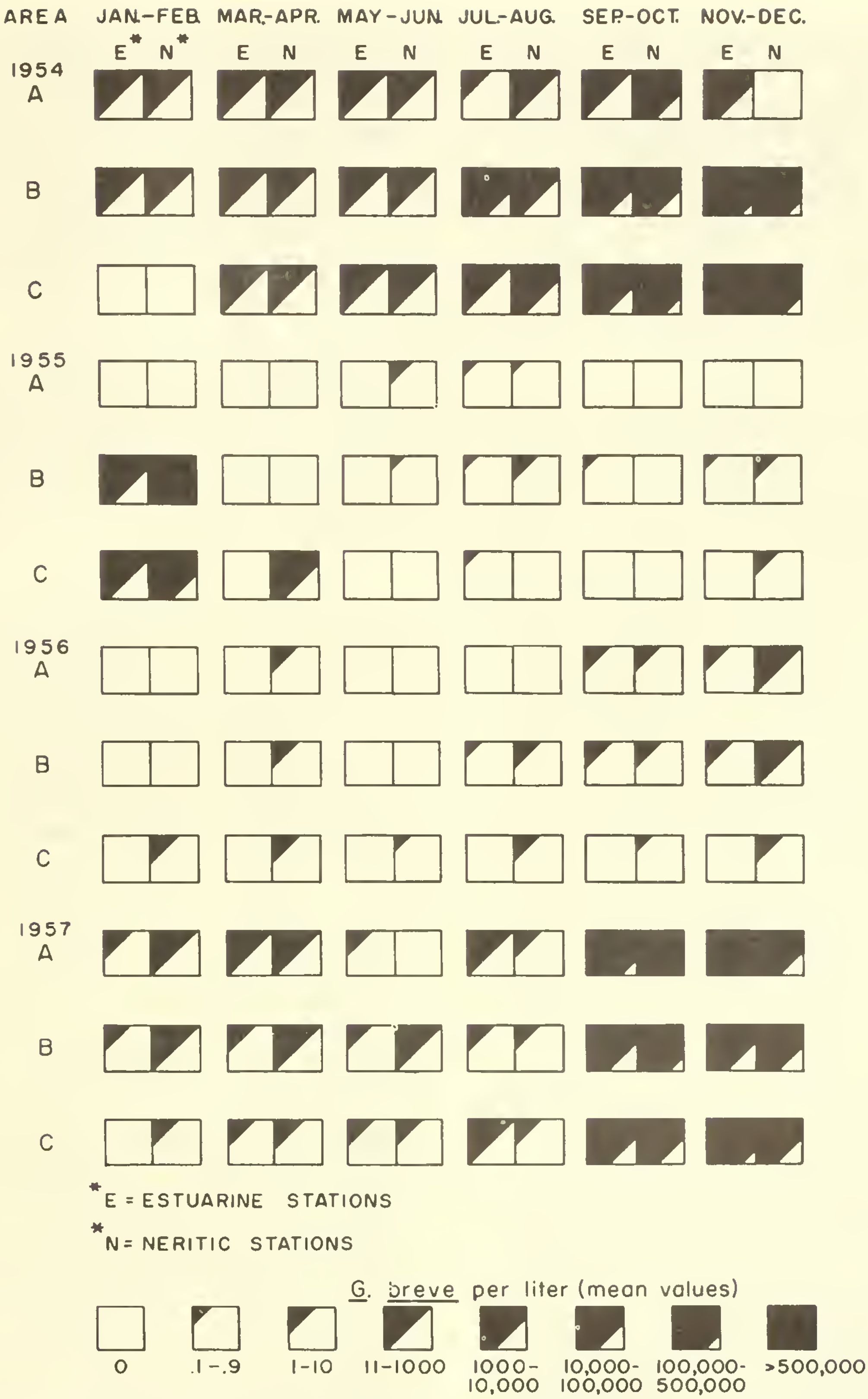

Figure 6.--Bimonthly occurrence and numbers of G. breve by areas in the surface waters of the west Florida coast (1954-57).

G. breve was widely distributed during the year, although no blooms were noted. During January-April, G. breve was present only in the neritic waters of areas A, B, and C, from Sarasota to Cape Romano. From May through August, its distribution was primarily confined to neritic waters in areas B and C, from Sanibel Island to the Florida Everglages (fig. 6). During the remainder of the year, the organism was distributed in both estuarine and neritic waters in areas A, B, and C, from Clearwater to Cape Romano. The G. breve incidence during September-December was higher during 1956 than in comparable months of 1955 (table 1).

1957.--From January to September, G. breve was observed in nonbloom numbers in areas A, B, and C. These areas included Tampa Bay, Sarasota Bay, Charlotte Harbor, San Carlos Bay, the Florida Everglades, and their adjacent neritic waters. During March, G. breve was found in area D off Cape Sable. This was the only occurrence of the organism in area D.

The incidence and numbers of G. breve increased in September and October, and reached the highest proportions since 1954 (fig. 6). Dense concentrations (11,900-136,-000/1.) were detected on Sept. 23 and 24 in area A off Egmont Key and Clearwater. The first fish kills of the 1957 red-tide outbreak were reported off St. Petersburg Beach on Sept. 26. From this date a progressive increase in the number of blooms was observed in areas A through C. G. breve counts as high as 3,310,000/1. were noted off Anclote Key (Tarpon Springs) by Oct. 4. During the same month, blooms and fish kills occurred from Sanibel Island to Naples in areas B and C. By November, distribution of the organism extended as far south as the Shark River in the Florida Everglades. As many as 1,100,000/1. were present in water samples from Big Marco Pass on Nov. 4. Blooms also were observed in the estuarine and neritic waters extending from Boca Ciega Bay (St. Petersburg) to Venice in areas A and B. (fig. 6).

Occurrence of G. breve in Relation to Salinity and Temperature

Over 400 fresh-water samples were collected from Lake Okeechobee, Tamiami Canal, and the Peace, Myakka, and Calosahatchee Rivers. G. breve was not found in these samples. It was noted at river mouths only during red-tide outbreaks in 1954 and 1957. It occurred in low numbers from October through December 1957 near the mouth of the Manatee River at salinities ranging from 25.37-29.27‰. This occurrence coincided with high concentrations of G. breve in the adjacent neritic waters of area A (fig. 6).

Most positive samples occurred at salinities from 31.0-34.9‰ (table 2). Lethal concentrations (250,000/1.) were observed at salinities ranging from 21.0-36.9‰. The lowest and highest observed salinities for this flagellate were 21.2‰ and 37.5‰. G. breve was completely absent at salinities above 37.5‰.

The frequency distribution of G. breve at observed water temperatures was determined in 9,108 samples (table 2). G. breve was noted in the temperature range 10.3°-33.2° C. Most blooms occurred from 14.0°-25.9° C. Lethal concentrations were noted at 14.0°-31.9° C. Most positive samples and lethal concentrations occurred between 16.0°-17.9° C.

Vertical Dispersion

Using all paired surface and bottom samples taken simultaneously during the 4-year period, we found that G. breve incidence was higher in surface than in bottom samples (fig. 7). This was generally true for the entire sampling period and all areas. The majority of these samples were taken during the daylight hours between 0800 and 1700.

DISCUSSION

The distribution of G. breve during this study extended from Anclote Key south to the Shark River in the Florida Everglades, a range of nearly 200 linear miles along the west coast of Florida. The organism was not found in Florida Bay or off the Florida Keys. Davis (1948) reported G. breve during the 1946-47 red-tide outbreak in the waters off the Florida Keys. Menzel stated that G. breve was found in Alligator Harbor about 130 miles northwest of Anclote Key[1]. Isolated blooms were observed in the waters along the upper and lower Texas coast and in the western Gulf of Mexico (Wilson and Ray, 1956, and Collier, 1958). G. breve also was reported from the coast of Trinidad (Lackey, 1956). The distribution pattern observed during this study and by other investigations suggests that G. breve is endemic to the Gulf of Mexico and the Caribbean.

The frequent presence of G. breve in west coast Florida waters indicates that it may be considered a normal constituent of the resident phytoplankton population. Since its incidence during nonbloom periods is primarily confined to offshore waters, the organism probably is more neritic than estuarine (fig. 6). G. breve occurred in approximately equal frequency in both estuarine and neritic waters only during the red-tide outbreaks in 1954 and 1957. The offshore distribution usually extended 6-10 miles, although in March 1960 a bloom of 6,320,000/1. was detected 35 miles offshore (Hutton, 1960). During the red-tide outbreak of 1954, Lackey and Hynes (1955) reported G. breve in samples collected 140 miles southwest of Fort Myers, Fla. The

[1]R. W. Menzel (personal communication, 1957), Florida State University, Tallahassee, Fla.

Table 2.--Salinity, temperature, and incidence of G. breve in Florida waters (1954-57)

Salinity	Samples collected	Samples positive for G. breve	Samples containing G. breve in lethal concentration (250 or more/ml.) 2.5 x 10^5/l.
‰	Number	Percent	Percent
41.0-70.9	91	0	0
39.0-40.9	108	0	0
37.0-38.9	1,066	2.6	0
35.0-36.9	4,123	10.3	0.4
33.0-34.9	2,015	34.4	5.7
31.0-32.9	660	34.2	5.0
29.0-30.9	276	21.0	2.2
27.0-28.9	166	18.1	0.6
25.0-26.9	122	12.3	0
23.0-24.9	65	10.8	4.6
21.0-22.9	52	9.6	3.8
0.0-20.9	437	0	0
Temperature			
°C.			
34.0-35.9	4	0	0
32.0-33.9	147	4.8	0
30.0-31.9	1,682	7.2	0.1
28.0-29.9	1,882	10.2	0.4
26.0-27.9	806	13.3	1.2
24.0-25.9	1,034	20.9	3.3
22.0-23.9	1,231	24.4	3.3
20.0-21.9	931	28.8	2.8
18.0-19.9	745	27.4	2.9
16.0-17.9	395	40.5	7.3
14.0-15.9	168	29.2	3.6
12.0-13.9	66	25.8	0
10.0-11.9	16	37.5	0
0.00-9.9	1	0	0

presence of the organism in those areas indicates that it can exist in an oceanic environment.

G. breve concentrations varied throughout the investigation and exhibited patchy distribution. This "patchiness" was particularly noticeable during the outbreaks of red tide. Counts varied from 0 to 600,000/l. at stations from Egmont Channel to Venice Inlet in a period of less than 3 hours during Oct. 23, 1957 (table 3). Uneven distribution of dinoflagellates also has been observed in the North Sea (Lucas, 1942).

The majority of 1955 and 1956 samples contained less than 1000/l., which may be considered a resident population level (fig. 6). G. breve counts usually were higher in neritic than in estuarine waters during these years. In 1956, this organism was observed only in the neritic waters from Naples to the Florida Everglades. The highest numbers were recorded during blooms in 1954 and 1957. Counts of 7,500,000 and 100,000,000/l. were observed in two areas of dying fish during December of 1954 and 1957. Lasker and Smith (1954) reported 15,000,000/l. as the highest number observed during the 1946-47 red-tide outbreak. Lackey and Hynes (1955) reported 4,814,000/l. in 1954.

The densest concentrations and greatest numbers of the organism usually occurred during fall and winter (September-January) and often were preceded by a period of excessive rainfall (fig. 6 and table 4). During the red-tide year 1954, precipitation was 12.95 inches above normal in area C and 8.68 inches above normal in area D (table 4). In 1955 and 1956, which were not red-tide years, rainfall

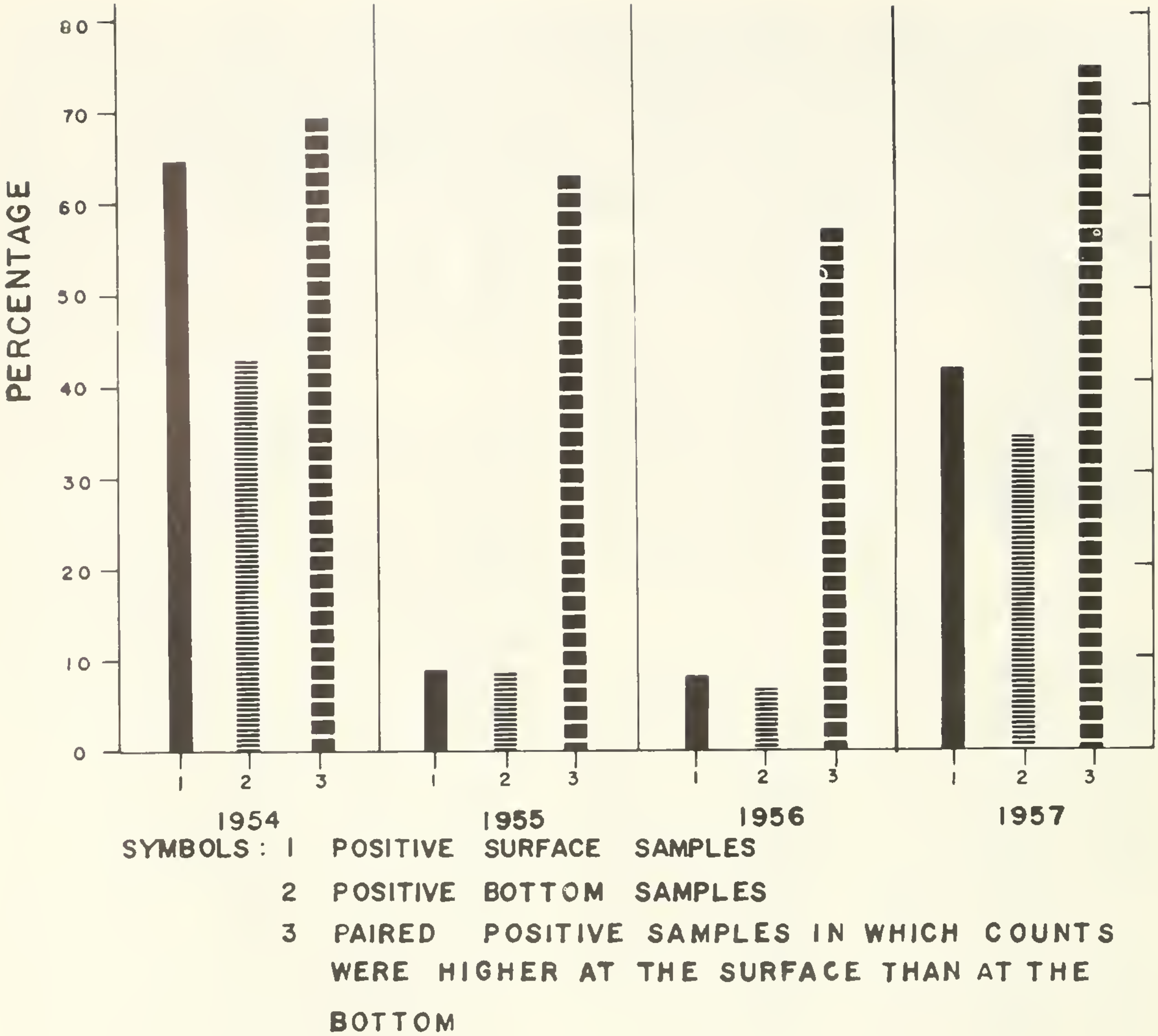

Figure 7.--Incidence of G. breve from simultaneously collected samples (1954-57).

was below normal in the entire sampling area. During 1957, the other red-tide year, rainfall was 10.29 and 20.49 inches above normal in areas A and B respectively. The major red-tide outbreaks in the fall and winter of 1954 and 1957 occurred in areas of abnormal rainfall. These observations agree with the hypothesis of Slobodkin (1953), who observed a close association of red tide along the west coast of Florida with periods of exceptionally heavy rainfall.

The seasonal occurrence and abundance of G. breve may be associated directly or indirectly with periods of heavy rainfall. Increased land drainage usually accompanies these rainy periods, ultimately bringing more nutrients into the adjoining estuaries and offshore waters (Harvey, 1957). Aldrich (1962) stressed that vitamins, trace elements, and chelators introduced by drainage waters into coastal environments were necessary to the growth of G. breve. Dragovich and May (1962) indicated that the mean copper concentrations in river waters draining into Tampa Bay are well below the levels toxic to G. breve. Bein (1957) concluded that phosphates do not limit the distribution of this organism because the coastal waters of west Florida contain sufficient phosphorus to support a red tide at all times of the year.

Salinity appears to have some association with the distribution and abundance of this organism. G. breve was never observed in high salinity >39.0‰ waters south of Cape Sable or in the upper portion of estuaries having salinities less than 21.0‰. The absence of G. breve at salinities below 21.0‰ and above 38.9‰ indicates that salinity may serve as a barrier to its distribution. Lethal concentrations of G. breve occurred only from 21.0-

Table 3.--Concentrations of G. breve in neritic and estuarine waters along the southwest Florida coast

General locality	Date (1957)	Time (EST)	Depth	Average per liter
				Number
Buoy No. 1 Egmont Channel	10/6	1202	S[1]	19,000
		"	B[2]	2,000
Off Longboat		1252	S	27,000
		"	B	500
Off New Pass		1326	S	500
		"	B	100
Off Big Sarasota Pass		1417	S	100
		"	B	0
Off Midnight Pass		1434	S	0
		"	B	0
Off Venice Inlet		1456	S	0
		"	B	0
1/4 mile west of Stump Pass		1547	S	0
		"	B	0
1/2 mile west of Gasparilla Pass		1613	S	0
		"	B	0
Boca Grande Pass		1640	S	0
		"	B	0
Captiva Pass		1707	S	0
		"	B	0
Redfish Pass		1721	S	0
		"	B	0
Buoy No. 2 Egmont Channel	10/11	1220	S	360,000
		"	B	300,000
1 mile east Buoy No. 1 Egmont Channel		1233	S	1,780,000
		"	B	320,000
Buoy No. 1 Egmont Channel		1250	S	480,000
		"	B	340,000
1-1/2 miles east Buoy No. 1 Egmont Channel		1343	S	40,000,000
		"	B	5,000,000
Buoy No. 2 Egmont Channel	10/23	0829	S	600,000
		"	B	180,000
Bell Buoy Southwest Channel		0844	S	280,000
		"	B	140,000
Off Longboat Pass		0919	S	280,000
		"	B	80,000
Off New Pass		0952	S	300,000
		"	B	160,000
Off Big Sarasota Pass		1005	S	6,000
		"	B	2,000
Off Midnight Pass		1023	S	0
		"	B	0
Off Venice Inlet		1045	S	10,000
		"	B	200

[1] S = surface.
[2] B = bottom.

36.9‰ and most frequently from 31.0-34.9‰ (table 2). Aldrich and Wilson (1960) observed no instances of optimal growth in cultures below 24‰ and considered the salinity range 27-37‰ best for the organism in laboratory experiments. The main differences between their work and our field data may result from the relatively few water samples in our low salinity range. In nature the organism is also subjected to a more gradual salinity change.

Temperature data indicate that the organism can survive a relatively wide temperature range and is limited only by high or low water temperatures. The most favorable temperature range for G. breve blooms appears to be 14.0°-25.9° C. (table 2). This may account for

the reduction of the organism to nonbloom levels when red-tide periods extend into a late summer characterized by unusually high temperatures or into a winter when unusually low temperatures prevail. The optimal temperatures for G. breve usually occur in spring and fall.

Another major factor which may influence distribution of G. breve is water movement along the west coast of Florida. Preliminary hydrographic studies in the coastal waters from Naples to Sanibel Island indicated the presence of a south to north current in relatively shallow waters. The findings agree with Hela (1956), who found a northbound current along the Florida southwest coast. Hela also postulated that red tides always start in the south and move northward. Our data on G. breve distribution indicate that this is not necessarily true. During the 1957 outbreak, the opposite (north to south) distributional pattern was evident. At the beginning of the outbreak, most G. breve and most of the fish kills occurred in area A, the Tarpon Springs-St. Petersburg section. This was followed by a more southerly incidence of G. breve in the estuarine and neritic waters of areas B and C during the remainder of the year.

Our data indicate higher concentrations near the surface during daylight hours (fig. 7). Phototropism of G. breve in nature and in the laboratory was observed also by Hela (1956) and Aldrich (1962). Further laboratory studies by Aldrich (unpublished results)[2] showed that G. breve survived for a few days without light and that populations maintained at a low light level (200/foot-candles) declined. This suggests that survival and vertical distribution of G. breve in nature depend on solar radiation.

Our investigation of the distribution of G. breve has established the range of the organism along the Florida west coast and described certain hydrographic and meteorological conditions existing during bloom and nonbloom periods. Further studies of this organism would be necessary to fully understand its environmental requirements and possible means of control.

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[2]David V. Aldrich. 1960. Physiology of the Florida Red Tide Organism. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Cir. 92, p. 42.

Table 4.--Monthly and annual total precipitation in inches at selected locations along the west Florida coast (1954-57)[1]

1954

	Area A Tampa		Area B Punta Gorda		Area C Everglades		Area D Tavernier	
Month	Precipitation		Precipitation		Precipitation		Precipitation	
Jan.	0.99	(1.99)	0.38	(2.24)	0.05	(2.00)	0.99	(1.90)
Feb.	1.58	(2.50)	2.03	(1.83)	-	-	3.01	(1.70)
Mar.	2.01	(3.12)	0.96	(2.21)	6.49	(3.15)	2.89	(1.60)
April	2.48	(2.51)	4.12	(2.20)	7.87	(1.35)	3.76	(1.67)
May	5.90	(3.29)	5.54	(3.61)	11.33	(4.95)	5.52	(4.20)
June	4.57	(7.77)	6.25	(7.48)	9.56	(6.95)	6.28	(4.31)
July	6.73	(8.11)	11.01	(7.54)	7.52	(7.30)	8.64	(7.33)
Aug.	4.73	(8.06)	5.33	(8.05)	7.28	(8.80)	7.20	(5.27)
Sept.	6.35	(6.45)	8.26	(8.22)	9.52	(8.55)	6.29	(7.67)
Oct.	0.63	(3.14)	2.52	(3.97)	3.03	(5.70)	4.51	(8.02)
Nov.	5.38	(1.04)	1.40	(1.56)	.79	(1.45)	6.73	(2.44)
Dec.	1.85	(1.96)	1.53	(1.85)	.91	(1.20)	.49	(1.52)
TOTAL	43.20	(49.94)	49.33	(50.76)	64.35	(51.40)	56.31	(47.63)

1955

	Area A Tampa		Area B Punta Gorda		Area C Everglades		Area D Tavernier	
Jan.	2.59	(1.99)	1.31	(2.24)	0.73	(2.00)	0.46	(1.90)
Feb.	2.73	(2.50)	1.14	(1.83)	0.35	(1.30)	0.51	(1.70)
Mar.	2.65	(3.12)	1.08	(2.21)	0.14	(1.85)	1.05	(1.60)
April	1.23	(2.51)	1.85	(2.20)	2.17	(1.35)	1.37	(1.67)
May	0.72	(3.29)	2.13	(3.61)	4.00	(4.95)	2.33	(4.20)
June	2.55	(7.77)	5.64	(7.48)	13.59	(6.95)	11.17	(4.31)
July	11.90	(8.11)	5.84	(7.90)	6.63	(7.30)	7.14	(3.12)
Aug.	9.57	(8.06)	3.93	(8.05)	7.17	(8.80)	4.76	(5.27)
Sept.	8.82	(6.45)	10.69	(8.22)	9.20	(8.55)	4.94	(7.67)
Oct.	3.23	(3.14)	0.98	(3.97)	3.64	(5.70)	4.97	(8.02)
Nov.	2.15	(1.04)	0.31	(1.56)	0.75	(1.45)	0.47	(2.44)
Dec.	0.67	(1.96)	0.53	(1.85)	2.11	(1.20)	1.44	(1.52)
TOTAL	48.81	(49.94)	35.43	(51.12)	50.48	(51.40)	40.61	(43.42)

Table 4.--Monthly and annual total precipitation in inches at selected locations along the west Florida coast (1954-57)[1]--Continued

1956

Month	Area A Tampa Precipitation	Area B Punta Gorda Precipitation	Area C Everglades Precipitation	Area D Tavernier Precipitation
Jan.	2.02 (1.99)	0.88 (1.56)	1.64 (1.58)	0.34
Feb.	1.37 (2.60)	2.59 (2.33)	0.78 (1.43)	0.74
Mar.	0.06 (3.12)	0.00 (2.41)	0.09 (2.21)	T
April	2.08 (2.51)	2.27 (2.84)	4.67 (2.63)	1.64
May	2.15 (3.29)	4.54 (3.14)	8.60 (4.63)	0.33
June	2.86 (7.77)	4.36 (9.18)	3.43 (8.87)	4.36
July	3.69 (8.11)	5.14 (7.98)	4.77 (8.40)	0.70
Aug.	6.60 (8.06)	6.24 (6.80)	6.62 (7.27)	1.50
Sept.	3.90 (6.45)	9.00 (8.18)	3.84 (9.75)	12.39
Oct.	3.50 (3.14)	2.99 (3.78)	4.57 (4.24)	9.46
Nov.	0.45 (1.04)	1.25 (1.29)	0.77 (1.42)	0.60
Dec.	0.21 (1.96)	0.41 (1.47)	0.14 (1.35)	0.98
TOTAL	28.89 (50.04)	39.67 (50.96)	39.92 (53.78)	33.04

1957

Month	Area A Tampa Precipitation	Area B Punta Gorda Precipitation	Area C Everglades Precipitation	Area D Tavernier Precipitation
Jan.	1.53 (1.99)	1.24 (1.56)	0.39 (1.58)	0.31
Feb.	3.25 (2.50)	3.19 (2.33)	4.84 (1.43)	4.32
Mar.	6.98 (3.12)	5.37 (2.41)	0.75 (2.21)	1.47
April	6.59 (2.51)	7.93 (2.84)	1.64 (2.63)	2.30
May	7.21 (3.29)	5.91 (3.14)	6.98 (4.63)	5.17
June	11.11 (7.77)	6.77 (9.18)	5.99 (8.87)	3.45
July	10.61 (8.11)	9.65 (7.98)	6.92 (8.40)	6.35
Aug.	11.74 (8.06)	7.47 (6.80)	7.34 (7.27)	6.00
Sept.	5.95 (6.45)	6.52 (8.18)	6.69 (9.75)	6.71
Oct.	2.28 (3.14)	3.72 (3.78)	6.68 (4.24)	6.65
Nov.	1.44 (1.04)	1.52 (1.29)	0.14 (1.42)	1.35
Dec.	1.74 (1.96)	1.63 (1.47)	2.15 (1.35)	6.83
TOTAL	70.43 (49.94)	60.92 (50.96)	50.51 (53.78)	50.91

[1] Compiled from U.S. Department of Commerce, Weather Bureau data. Numbers in parentheses are long-term means established by Weather Bureau.

SUMMARY

During the 4-year observation period, G. breve was present in nonbloom numbers throughout the year in estuarine and neritic waters from Tarpon Springs to the Florida Evergaldes. The lethal concentration for fish was considered about 250,000/l. In 1954 and 1957, concentrations as high as 7,500,000-100,000,000/l. were noted. The vertical distribution of the organism showed a higher concentration near the surface than near the bottom, during daylight.

Red-tide outbreaks and accompanying fish kills were most pronounced in the fall and winter, usually after periods of heavy rainfall. The highest numbers of G. breve during 1954 were found from Venice south to the Florida Everglades. In 1955, blooms were confined to the estuarine and neritic waters from Sanibel Island to Cape Sable. No fish kills occurred during 1956. Concentrations of G. breve essentially remained less than 1,000/l. during 1955 and 1956. The 1957 red-tide outbreak was characterized by an initial buildup of the organism in the neritic waters off the major drainage areas: Tampa Bay, Sarasota Bay, Charlotte Harbor, San Carlos Bay, and the Florida Everglades. The highest incidence and numbers of G. breve were recorded off Egmont Key and St. Petersburg Beach during September and October 1957.

G. breve was not found in waters with salinity lower than 21.0‰. Lethal concentrations occurred at 21.0-36.9‰ salinities and most frequently at 31.0-34.9‰; it was completely absent at salinities above 37.5‰.

The observed temperature range for G. breve was 10.3° - 33.2° C. The majority of blooms occurred from 14.0° - 25.9° C. Temperatures below 14.0° C. and above 32.0° C. appear to limit the distribution of this organism.

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LITERATURE CITED

ALDRICH, DAVID V.
1962. Photoautotrophy in Gymnodinium breve Davis. Science, vol. 137, no. 3534, p. 988-990.

ALDRICH, DAVID V., and WILLIAM B. WILSON.
1960. The effect of salinity on growth of Gymnodinium breve Davis. Biological Bulletin, vol. 119, no. 1, p. 57-64.

BEIN, SELWYN J.
1957. The relationship of total phosphorus concentration in sea water to red-tide blooms. Bulletin of Marine Science of the Gulf and Caribbean, vol. 7, no. 4, p. 316-329.

CHEW, FRANK.
1961. Some implications of the highly saline water off the southwest coast of Florida. Journal of Geophysical Research, vol. 66, no. 8, p. 2445-2454.

COLLIER, ALBERT.
1958. Some biochemical aspects of red tides and related oceanographic problems. Limnology and Oceanography, vol. 3, no. 1, p. 33-39.

DAVIS, CHARLES C.
1948. Gymnodinium brevis sp.nov., a cause of discolored water and animal mortality in the Gulf of Mexico. Botanical Gazette, vol. 109, no. 3, p. 358-360.

DRAGOVICH, ALEXANDER.
1963. Hydrology and plankton of coastal waters of Naples, Florida. Quarterly Journal of the Florida Academy of Science, vol. 26, no. 4, p. 22-47.

DRAGOVICH, ALEXANDER, JOHN H. FINUCANE, and BILLIE Z. MAY.
1961. Counts of red tide organisms, Gymnodinium breve, and associated oceanographic data from Florida west coast, 1957-59. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 369, 175 p.

DRAGOVICH, ALEXANDER, and BILLIE Z. MAY.
1962. Hydrological characteristics of Tampa Bay tributaries. U.S. Fish and Wildlife Service, Fishery Bulletin 205, vol. 62, p. 163-176.

FINUCANE, JOHN H., and ALEXANDER DRAGOVICH.
1959. Counts of red tide organisms, Gymnodinium breve, and associated oceanographic data from Florida west coast, 1954-57. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 289, 220 p.

HARVEY, H. W.
1957. The chemistry and fertility of sea waters. University Press, Cambridge, 234 p.

HELA, ILMO.
1956. A pattern of coastal circulation inferred from synoptic salinity data. Bulletin of Marine Science of the Gulf and Caribbean, vol. 6, no. 1, p. 74-83.

HUTTON, ROBERT F.
1956. An annotated bibliography of red tides occurring in the marine waters of Florida. Quarterly Journal of the Florida Academy of Sciences, vol. 19, nos. 2-3, p. 124-146.
1960. Notes on the causes of discolored water along the southwestern coast of Florida. Quarterly Journal of the Florida Academy of Sciences, vol. 23, no. 2, p. 163-164.

LACKEY, JAMES B.
1956. Known geographic range of Gymnodinium brevis Davis. Quarterly Journal of the Florida Academy of Sciences, vol. 19, no. 1, p. 71.

LACKEY, JAMES B., and JACQUELINE A. HYNES.
1955. The Florida Gulf coast red tide. Engineering Progress at the University of Florida, vol. 9, no. 2, 24 p.

LASKER, REUBEN, and F. G. WALTON SMITH.
1954. Red tide. U.S. Fish and Wildlife Service, Fishery Bulletin 89, vol. 55, p. 173-176.

LUCAS, C. E.
1942. Continuous plankton records: Phytoplankton in the North Sea, 1938-39. Part II. - Dinoflagellates, Phaeocystis, etc. Hull Bulletins of Marine Ecology, vo. 2, no. 9, p. 47-70.

RAY, SAMMY M., and WILLIAM B. WILSON.
1957. Effects of unialgal and bacteria-free cultures of Gymnodinium brevis on fish, and notes on related studies with bacteria. U.S. Fish and Wildlife Service, Fishery Bulletin 123, vol. 57, p. 469-496.

SLOBODKIN, L. BASIL.
1953. A possible initial condition for red tides on the coast of Florida. Journal of Marine Research, vol. 12, no. 1, p. 148-155.

STARR, T. J.
1958. Notes on a toxin from Gymnodinium breve. Texas Report Biological Medicine, vol. 16, p. 97-106.

WILSON, W. B., and S. M. RAY.
1956. The occurrence of Gymnodinium brevis in the western Gulf of Mexico. Ecology, vol. 37, no. 2, 388 p.

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